



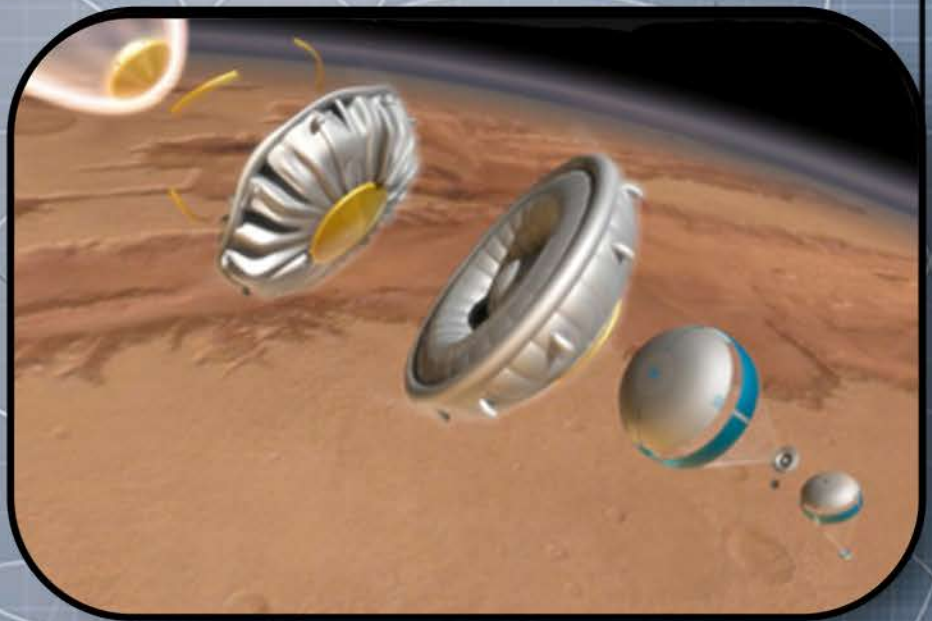
National Aeronautics and
Space Administration



21CCLC NASA STEM Challenge

Parachuting onto Mars

Facilitation Guide



FACILITATOR'S WELCOME

Dear 21CCLC STEM Facilitators,

Welcome to this year's 2014-2015 STEM Engineering Design Challenge Team! As part of this team, you will play an integral part in helping today's students become tomorrow's scientists, technicians, engineers and mathematicians. Engineering Design Challenges, like the one included in this guide. Through the Engineering Design Challenge (EDC), students will participate in authentic learning experiences that allow them to develop valuable skills through rigorous and engaging science, technology, engineering, and mathematics (STEM) content.

As a 21CCLC STEM facilitator, you are helping your students use their creativity, curiosity, analytical thinking as they utilize the **Engineering Design Process (EDP)**. Solving problems utilizing the EDP will be key to the success of NASA's future engineering workforce.

Through the design challenge, **Parachuting onto Mars**, students will work in small teams of no more than four students, to design a device to slow the descent of a space craft or probe while protecting its cargo for a successful landing.

The major real-world concepts of this challenge are:

1. **Engineering Design Process (EDP)**
2. **Calculating Surface Area**
3. **Measuring Mass**
4. **Testing Drag**

This Facilitator's Guide is designed to provide the facilitator with important information to use in planning and conducting the challenge. It includes simple explanations of relevant background information, clear step-by-step instructions, reflective data sheets, and concise rubrics for evaluation of student performance. You will be expected to use all of the included materials with your students. You can adapt the timeline to fit your classroom schedule.

NASA supports educators and facilitators, like you, who play a key role in preparing students for careers in STEM fields through engaging content. Thank you for helping us share this learning experience with your students.

Engineering Design Challenge Team

US Department of Education
NASA Office of Education

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This challenge was adapted and content modified from “Amazing Supersonic Decelerator: Parachuting on to Mars”

INTRODUCTION



FACILITATOR'S OVERVIEW

The US Department of Education and NASA's Office of Education have worked together to create an **Engineering Design Challenge (EDC)** that teaches students about the **Engineering Design Process (EDP)**. This process will help students complete the Engineering Design Challenge.

The EDC serves as an authentic standards-based investigation. It allows students to engage in the process of solving problems in a manner that today's scientists and engineers are utilizing. This EDC provides students with opportunities to gain tangible skills that are essential in STEM careers.

This guide is organized as follows:

1. **Introductory Materials** – Establishes a common basic level of understanding about the Engineering Design Process and its relation to this challenge. The introductory materials also include an alignment to Next Generation Science Standards and the Common Core State Standards for Mathematics, as well as background information highlighting NASA's science and research related to landing a vehicle on Mars.
2. **Facilitator Pages** – Provides instructions for facilitators to use throughout the design challenge. Also, included in this section are tools for you to use to assess student understanding throughout all steps of the challenge.
3. **Student Challenge Journal** – Contains prompts and tools to guide students through the cycle of steps in the Engineering Design Process, while documenting their work through each step.
4. **Support Materials** – Consists of information to supplement and enhance and build on the EDC.

These user-friendly sections are provided to help you support your students as they work in teams to complete the EDC. At the conclusion of the EDC, your students will be required to articulate the steps taken in the Engineering Design Process in a video each team will create. Good luck as you help create the next generation of STEM professionals!

For more information, and to access the Help Desk, visit the NASA STEM Challenges website at <http://y4y.ed.gov/stemchallenge/nasa>.

THE BASICS OF ENGINEERING DESIGN

What is an Engineer? Engineers are at the heart of every Engineering Design Challenge. Engineers are people who design and build things that we use every day. The video at the link below will explain the role of an engineer and can be shared with your students: http://youtu.be/wE-z_TJyzil. After viewing the video ask the students as a class to describe what an engineer does.



Figure 1: Aerospace Engineer Chris Randall tests rocket parts and life support systems to ensure they work as planned. (NASA)



Figure 2: Simulation System Engineer Debbie Martinez works on developing a general aviation flight simulation software. (NASA)

What is an Engineering Design Challenge? An Engineering Design Challenge is developed to assist students to understand the Engineering Design Process. The students are presented with a challenge problem and, using the process, they participate in teams to complete activities and experiments to develop solutions to the original problem. These challenges facilitate teamwork, problem solving, and brainstorming ideas very similar to what real-world engineers encounter in their careers.

Engineering Design Process

What is the Engineering Design Process? The engineering design process is a cycle of steps that lead to the development of a new product or system. The cycle is repeated to continuously refine and improve the product. In this design challenge, students are to complete each step and document their work as they develop and test their design. To accomplish this task, the students need to perform each of the steps in the Engineering Design Process and repeat the cycle, as many times as time and resources allow, to develop the best end product. Some steps (for example, Researching the Need or Problem) will only need to be briefly revisited as a checkup that teams are still on track. Some steps (for example, Test and Evaluate the Solution) will need to be completely redone.

THE ENGINEERING DESIGN PROCESS

STEP 1: Identify the Need or Problem – Students, working in teams; state the challenge problem in their own words. Example: How can I design a _____ that will _____?

STEP 2: Research the Need or Problem – Teams use resources, from the Internet, library, or discussions with experts, to examine the how this problem is currently being solved or how similar problems are being solved.

STEP 3: Develop Possible Solutions – Team members draw on their mathematic and scientific knowledge to brainstorm all the possible ways that they might solve the problem. Out of their ideas, they choose the most promising options, and refine their solution by quickly sketching in two or three dimensions. Labels and arrows should be included to identify parts.

STEP 4: Select the Best Possible Solution(s) – Team members share their ideas and answer questions from other team members. The team then discusses and records strengths and weaknesses from each design and determines which solution(s) best meet(s) the original need or solve(s) the original problem. This may include features from more than one design. The team writes a statement that describes why they chose their solution.

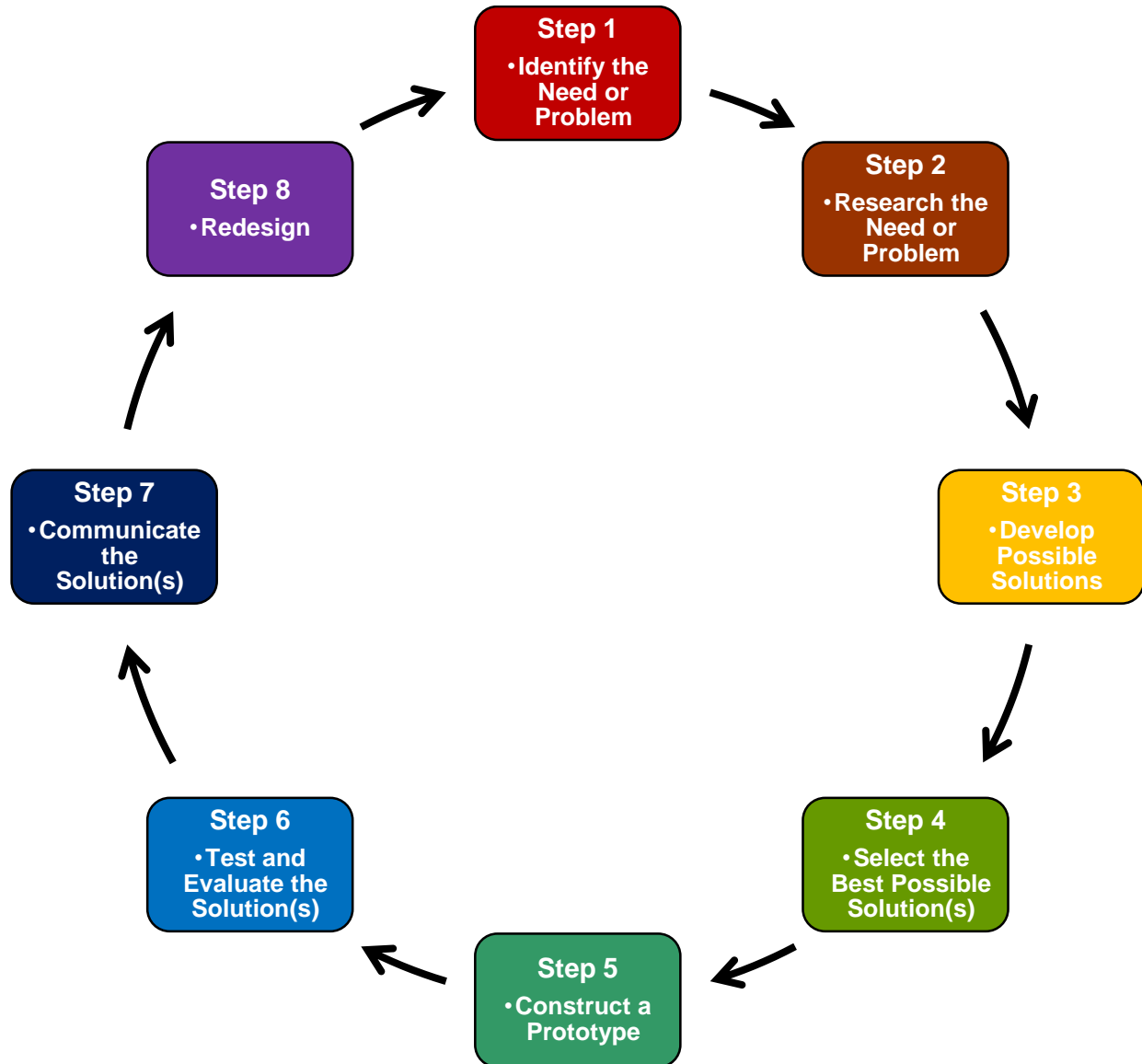
STEP 5: Construct a Prototype – Team members construct a full-size or scale model of the selected solution(s) in two or three dimensions. The facilitator helps to identify and acquire appropriate modeling materials and tools.

STEP 6: Test and Evaluate the Solution(s) – Team members test their model to determine how effective it was in solving the need or problem. Data is collected to serve as evidence of their success or need for improvement.

STEP 7: Communicate the Solution(s) – Team members record and share what was learned about their design based on testing. They make a presentation that includes how the solution(s) best solved the need or problem and any improvements that could be made. They may enlist students from other teams to review the solution and help identify changes.

STEP 8: Redesign – Team members consider modifications to their solution(s) based on the information gathered during the tests and presentation. Teams revisit the original need or problem to ensure their modifications still meet the necessary criteria and constraints, restarting the cycle of the Engineering Design Process.

THE ENGINEERING DESIGN PROCESS



This Engineering Design Process model was adapted from the Massachusetts Science and Technology/Engineering Curriculum Framework (published October 2006, <http://www.doe.mass.edu/frameworks/scitech/1006.pdf>).

STANDARDS ADDRESSED

Next Generation Science Standards	Common Core State Standards Mathematics
<p>Practices</p> <ol style="list-style-type: none"> 1. Asking questions, defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using math and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information <p>Cross-Cutting Concepts</p> <ol style="list-style-type: none"> 1. Patterns 2. Cause and effect 3. Scale 4. Systems and system models 5. Energy and matter 6. Structure and function <p>Core and Component Ideas</p> <p><i>Physical Science</i></p> <p>PS2: Motion and Stability PS2.A: Forces and motion PS2.B: Types of interactions</p> <p><i>Earth and Space Science</i></p> <p>ESS1.B Earth and the Solar System Engineering, Technology, and Applications of Science ETS1.A: Defining and delimiting an engineering problem ETS1.B: Developing possible solutions ETS1.C: Optimizing the design solution ETS2.A: Interdependence of Science, Engineering, and Technology</p>	<p><i>Standards for Mathematical Practice</i></p> <p>MP1: Make sense of problems and persevere in solving them MP2: Reason abstractly and quantitatively MP3: Construct viable arguments and critique the reasoning of others MP4: Model with mathematics MP5: Use appropriate tools strategically MP6: Attend to precision</p> <p>Grades 6-8</p> <p><i>Expression and Equations</i> – Reason about and solve one- variable equations. Represent and analyze quantitative relationships between dependent and independent variables</p> <p><i>Geometry</i> – Solve real-world and mathematical problems involving area, surface area, angles, and volume</p> <p><i>Statistics and Probability</i> – Develop understanding of statistical variability. Summarize and describe distributions</p>

BACKGROUND INFORMATION: MARS

What is Mars?

Mars is the fourth planet from the sun and the next planet beyond Earth. It is, on average, more than 228 million km from the sun. Mars is about one-half the size of Earth. Known as the “Red Planet,” Mars gets its red color from the iron in its soil.

Mars is named for the ancient Roman god of war. The ancient Greeks called the planet Ares. The Romans and Greeks associated the planet with war because its color resembles the color of blood.

Mars has two small moons, Phobos and Deimos. They are named for the sons of Ares. In Greek, Phobos means “fear,” and Deimos means “terror.”



Figure 3: Photograph of Mars taken by the Hubble Space Telescope (NASA)

What is Mars Like?

Mars is very cold. The average temperature on Mars is -62° Celsius - far below the freezing point of water. Its surface is rocky and covered with canyons, inactive volcanoes, and craters. Red dust covers most of the surface. Although the Martian atmosphere is considerably different than Earth's, Mars does have clouds and wind. Sometimes the wind blows the red dust into storms. The dust storms can be seen from Earth using telescopes, and resemble tornados on Mars surface. Mars has about one-third the gravity of Earth. A rock dropped on Mars would fall more slowly than a rock falls on Earth. A person who weighs 100 pounds on Earth would only weigh about 37 pounds on Mars because of the reduced gravity.

What is in Mars' Atmosphere?

The atmosphere of Mars is about 100 times thinner than Earth's. This thin atmosphere makes it very difficult to land on the surface of Mars. Combined with the dust storms, mechanical operations, such as landers and rovers, can be very challenging on the planet. The Martian atmosphere has much less oxygen and far more carbon dioxide than the Earth's.

The Martian atmosphere consists of:

- Carbon dioxide: 95.32 percent
- Nitrogen: 2.7 percent
- Argon: 1.6 percent
- Oxygen: 0.13 percent
- Carbon monoxide: 0.08 percent

Also, minor amounts of: water, nitrogen oxide, neon, hydrogen-deuterium-oxygen, krypton, and xenon.

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What has NASA Learned about Mars?

NASA has used both orbiting spacecraft and robots to learn more about Mars. In 1965, Mariner 4 flew past Mars and became the first NASA spacecraft to take close-up images of another planet. In 1976, Viking 1 and Viking 2 were the first NASA spacecraft to land on Mars. Both spacecraft took images and collected science data on the Martian surface.

Since then, several spacecraft have flown near or landed on Mars. Scientists are particularly interested in searching for clues of water on Mars. Living things need water to survive. So, finding evidence that water exists or used to exist on Mars would mean that there could be or could have been life on the planet.

How is NASA Exploring Mars Today?

Today, three spacecraft are orbiting Mars. The spacecraft are using scientific tools to collect information like temperature and the kinds of minerals on Mars. They are also taking images and searching for water. NASA has also landed four rovers – robots that can move around - on the surface of Mars for the purpose of taking images, conducting scientific experiments, and collecting data about the planet's soil and rocks. These rovers were named Sojourner, Spirit, Opportunity, and the latest Curiosity. NASA uses the images and information gathered by the spacecraft and rovers to help determine if life could have ever existed on Mars. Opportunity and Curiosity are still providing images and data to NASA.



Figure 4: Replicas of the successful Mars rovers, showing size relation. (NASA)

How will NASA Explore Mars in the Future?



Figure 5: Illustration of the Phoenix Lander prior to touchdown (NASA)

NASA plans to send more robots to Mars with the hope of one day collecting Martian soil and rocks and returning them back to Earth to be studied. A robotic lander named Phoenix landed on Mars in May 2008. Phoenix dug holes in the soil and examined the composition data under the Martian surface. Phoenix has provided evidence that water in the form of ice exists just under the surface. NASA is also working to eventually send astronauts to the Red Planet. To prepare for human missions to Mars, NASA is researching new kinds of habitats where astronauts can live. Scientists are studying how living in space affects humans, and how people living in space can grow plants for food.

Get more Information:

- NASA's Mars Exploration website - <http://mars.nasa.gov/http://mars.nasa.gov/>
- Mars Science Laboratory (MSL) Curiosity rover website - <http://mars.jpl.nasa.gov/msl/>
- <http://mars.nasa.gov/>

SAMPLE TIMELINE

The EDC must be completed within the eight-week challenge period. The following timeline serves as a suggestion for the eight-week implementation. You may structure the sessions to fit your needs.

EDC Weeks	EDP	Actions
Pre-EDC	Pre-EDP	Attend Training and Order Materials
Week 1	Step 1 Step 2 Step 3	Identify the Need or Problem Research the Need or Problem Develop Possible Solution(s)
Week 2	Step 4 Step 5	Select the Best Solution Construct a Prototype
Week 3	Step 6 Step 7	Test and Evaluate Solution Communicate Solution
Week 4	Step 8 Step 1 Step 2	Redesign the Model Identify the Need or Problem Research the Need or Problem
Week 5	Step 3 Step 4	Develop Possible Solutions Select the Best Solution
Week 6	Step 5 Step 6	Construct a Prototype Test and Evaluate Solution
Week 7	Step 7 Step 8	Communicate Solutions (Compare Iterations) Recommend future Redesign
Week 8	Post-EDP	Create and Upload Student Videos

SAFETY

Safety is an important goal for all curricular areas of education. Safety issues are a special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote student development of knowledge and abilities in a safe learning environment.

It is the responsibility of the school's administration, teachers, and facilitators to provide a learning environment that is safe, up-to-date, and supportive of learning. Additionally, facilitators are responsible for their students' welfare in the classroom and laboratory.

Facilitators must be knowledgeable and diligent in providing a safe learning environment. Students should receive safety instructions relevant to the topics being taught. Assessments must accompany the lessons on safety, and records must be kept on student results. The facilitator must properly supervise students while they are working. The facilitator must inspect and maintain equipment and tools to ensure they are in proper working condition. Parents should be informed that a safe environment exists during the program. The facilitator should keep all students safe and assure that a safe environment exists and that proper procedures are being followed in the classroom and laboratory.

1. Students should demonstrate respect and courtesy for the ideas expressed by others in the group.
2. Students should use tools and equipment in a safe manner and assume responsibility for their safety, as well as for the safety of others.
3. Students should make safety a priority during all activities.
4. Students should wear safety goggles when conducting the EDC.
5. Facilitators should approve all drawings before students start building their designs.
6. Facilitators should look for potentially hazardous combinations of materials and flimsy designs of structures.
7. Facilitators should be sure resources are clean and dry with no sharp edges.
8. Facilitators should be the only ones using hot-glue guns and sharp instruments.
9. Facilitators should not allow students to bring additional materials for their designs without prior approval.
10. Facilitators should make sure all materials are not damaged or in disrepair.

FACILITATOR PAGES



USING A KLEW CHART

FACILITATOR DIRECTIONS: This KLEW chart can be used as a starting point for science investigation. Before you start the challenge, students should complete the **KNOW** section of this chart. It will allow students to share their prior knowledge and experiences (whether accurate or inaccurate). The **LEARN** section is after students are given background information about landing on Mars. This background information may come from videos, articles, and other supplemental information. The **EVIDENCE** section helps students to reinforce concepts that they learned using the background information and during the challenge by providing supporting information to validate what they stated in the LEARN column. In the **WONDER** section, students share any new questions they may still want to explore.

Please allow students to have flexibility in their answers. There are no right or wrong answers as long as the students answer the questions. Questions can be modified at the discretion of the Facilitator.

KNOW	LEARN	EVIDENCE	WONDER
What do I know about landing on Mars?	What did I learn about landing on Mars based on my research?	What evidence do I have that supports what I learned about landing on Mars?	What am I still wondering about landing on Mars?
NOTE: Have students complete this column before researching about landing on Mars.	NOTE: Have students complete this column after researching about landing on Mars.	NOTE: Have students complete this column using supporting information from articles, background information research, direct observation, and SME connections.	NOTE: Have students complete this column as they move through the process as a way of documenting ongoing questions.

THE ENGINEERING DESIGN CHALLENGE

You will be using the Engineering Design Process (EDP) to solve the challenge. The following pages will help you guide the students through the Challenge. You will break the students into teams of up to four students and follow each step of the EDP. Please note that both the Facilitator Pages and the Student Journal section are organized to align with the each step of the EDP.

THE CHALLENGE:

When NASA sends spacecraft to land on the surface of Mars, they travel at extreme speeds and need to slow down using some sort of drag device that slows the space capsule to prevent the machinery from crashing into the planet and damaging or destroying it. As missions increase in complexity and capability, the landers and rovers are getting heavier; and therefore, require even more effective drag devices.


You will work in a team to design, build, and test a drag device with the following criteria and constraints:

1. The drag device may only use materials provided.
2. The drag device must connect to a team-built cargo bay that is assembled using the template provided on page 39 of the Student Journal section.
3. The overall mass cannot exceed 50 grams.
4. The drag device must have at least five separate angled edges (rounded edges are allowed, but one big circle is not allowed).
5. It should protect the weighted cargo bay when it is dropped from a height of at least two meters. Surviving higher drops is preferred.



Figure 6: Artist rendering of the Low Density Supersonic Decelerator. (NASA)

- Digital scale or balance (1)
- Stopwatch (1)
- Measuring tape (1)
- Rulers (1 per team)
- Thin string like embroidery thread or fishing line
- Small sealable plastic storage bag to hold payload inside capsule (1 per team)
- Washers, marbles, or pennies to serve as mass
- Hole reinforcements or stickers with a hole punch
- Template for capsule (see page 39) – one for each team
- General building supplies for teams to assemble designs. These could include:

A photograph showing various school supplies arranged on a white surface. In the foreground, there is a black digital calculator, a silver ruler, a red pencil, a black pen, and a silver stapler. A yellow sticky note is also visible. The background is a plain white surface.

Pre-Activity Set-Up:

- For each group, prepare a plastic bag filled with 28 grams of washers, marbles, or pennies. This will serve as a simulated payload that will go into the capsule the teams assemble from the capsule template.
- Determine a unit cost for each of the materials available. Based on these unit costs, decide the maximum budget each team has to design their model. This value can be raised (budget increase) or lowered (budget cut) to adjust the level of challenge difficulty. Teams should itemize their budget using the Budget Planning Worksheet on page 38.

STEP-BY-STEP FACILITATION INSTRUCTIONS

Introduce the Challenge

Provide students the information covered in the challenge description found on page 15. Use the Challenge Rubric on page 26 in the Student Journal section to show students how their work during this challenge will be evaluated.

The Engineering Design Process Steps with Guiding Questions

STEP 1: Identify the Need or Problem

- Help facilitate learning by asking Guided Questions:
 - How can our team design a _____ that will _____?
 - What needs to be solved/improved?
 - What are we trying to accomplish?
- Review the Engineering Design Process with the students.
- Show the NASA BEST video titled “Repeatability” found at <https://www.youtube.com/watch?v=-2Az1KDn-YM>.
- Ask the team members why it is important to test their own designs.
- Discuss the Low Density Supersonic Decelerator Program and how engineers are working to develop various size drag devices for future space capsule.
- Videos and more information about Low Density Supersonic Decelerator available at: http://www.nasa.gov/mission_pages/tdm/ldsd/index.html. Video about landing on Mars is available at: <http://www.jpl.nasa.gov/video/index.php?id=1090>.
- Team members should identify the specific criteria and constraints of the design challenge. The drag device system will slow down the lander and keep the cargo safe (no broken or torn materials) during a drop from at least two meters high. The cargo (weights and space capsule template) and the drag device cannot exceed a total mass of 50 grams.
- Have team members fill out *Step 1: Identify the Need or Problem Worksheet*. On page 29 in the Student Journal section.

STEP 2: Research the Need or Problem

- Help facilitate learning by asking Guided Questions:
 - Where can you find more information about the topic?
 - What questions could you ask an expert?
- Help team members answer any questions they have about the challenge. Use the Internet or school library to research answers. Sample resources have been provided in the NASA Resources section on page 41. Any questions that are left unanswered should be written down and saved to ask during the NASA Subject Matter Expert connections.

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- Have the team members fill out the Step 2: Research the Need or Problem Worksheet page 30 in the Student Journal section.

STEP 3: Develop Possible Solutions

- Help facilitate learning by asking Guided Questions:
 - What are all the ways your team can imagine to solve this?
 - What do we need to do to add _____ to the design?
 - What might go wrong if we add _____ to the design?
- Each team member is to brainstorm and make sketches representing their ideas for a solution to the design challenge. The students will clearly label and identify each part of their drawing.
- Each team member should make sure that designs meet all constraints and criteria.
- Have the team members complete, Step 3: Develop Possible Solutions Worksheet, page 31 in the Student Journal section.

STEP 4: Select the Best Possible Solution(s)

- Help facilitate learning by asking Guided Questions:
 - Would it be better to _____ or _____?
 - Can we combine more than one plan?
 - Would a _____ fulfill the constraints of the challenge?
 - Do we have the resources to build a _____?
- Each team member will discuss their ideas and drawings with the rest of the team.
- The students will record the strengths and weaknesses of each of the designs.
- Have the student fill out Step 4: Develop Possible Solutions Worksheet page 32 in the Student Journal section.

STEP 5: Construct a Prototype

- Help facilitate learning by asking Guided Questions:
 - What resources does your team need to gather?
 - What is the plan?
 - Who is doing what?
- Each team will identify the design that appears to solve the problem.
- A final diagram of the design should be precisely drawn and labeled with a key.
- Each team is to determine what materials they will need to build their design and assign responsibilities for each team member for prototype completion.
- The final drawings should be approved by the facilitator before building begins.
- Teams will receive the materials they will need to build their model and complete the budget sheet representing the cost of their model.
- Using the drawings, the teams are to construct their prototypes.
- Teams should create a payload capsule using the Capsule Template found on page 39 of the Student Journal section. They will load the simulated payload prior to sealing the capsule with tape. The capsule should be attached to their drag device.

- Have each team member complete Step 5: Construct a Prototype Worksheet page 33 in the Student Journal section.

STEP 6: Test and Evaluate the Solution(s)

- Help facilitate learning by asking Guided Questions:
 - How did the prototype perform when tested?
 - Was the design successful?
- Review calculations necessary for determining surface area, speed, and mean average. The internet can provide formulas for these calculations.
- Visit each team and test their designs to ensure they are following all criteria and constraints.
- Each student team will test their model and record the results of each test.
- After the tests, the team members are to record the data they gathered from each drop.
- Have the students fill out pages 34 in the Student Journal section.

STEP 7: Communicate the Solution(s)

- Help facilitate learning by asking Guided Questions:
 - What did or did not work? Why?
 - What are the pros and cons of this solution?
- Team members are to document and report the results of their designs. They are to identify what changes were made with each iteration of design and what the team believed caused the design to succeed or fail during the tests.
- Have the team members complete row one of the Step 7 Communicate the Solutions(s) Worksheet, page 35, in the Student Journal section.

STEP 8: Redesign

- Help facilitate learning by asking Guided Questions:
 - How did the prototype perform when tested?
 - What did and didn't work?
 - What could be improved in the next iteration of this design?
- Teams are to identify the cause(s) of any problems that were observed during testing. They are to consider possible modifications to solve these problems.
- Have teams check that their redesigned model still meets all the criteria to solve the problem.
- Have the team members complete Step 8: Redesign Worksheet, page 36 in the Student Journal section.

From here, the cycle repeats with redefined problems and redesigned solutions as often as time and resources allow. With each additional iteration, and depending on the amount of redesign students put into one iteration, some steps may only need a quick revisit to be sure students are

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on track, while some steps will need to be completely redone. **In those cases, additional copies of cycle step pages should be made and added into the Student Journal Section.**

Submit Final Design

On the last design iteration, the documentation from Step 7 will be used to create a video of the design development and final design solution according to the Video Criteria and Video Rubric found on pages 27-28. Also at this time, use the Engineering Design Process worksheet on page 24 to test student knowledge of the entire design cycle.

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What was the greatest challenge or challenges for your team through this process?
2. What strategy or strategies did your team prove effective in overcoming your greatest challenge?
3. How did you use the Engineering Design Process to help you with your design?
4. Which drag device design characteristics provided the most reliable results?
5. Which design had the slowest descent (longest drop time)?
6. What was discovered about the relationship between surface area and drop time?

CHALLENGE CHECKLIST

Prior to the Challenge

Things to download, print, review, and copy:

- ☐ 1. Download and review the Presentation Slides for Students.
- ☐ 2. Download, print, and review the Video Criteria and Rubric. Make a copy for each team of students.
- ☐ 3. Download, print, and review the Educator Guide, Parachuting onto Mars. Print the Student Journal pages for each team of students.
- ☐ 4. Download or bookmark the Introductory Video, Telling Our Story with Video, and any other videos needed for your presentation.
- ☐ 5. Download and review the Technical Requirements for the Video.
- ☐ 6. Download, review, and print the Media Release Form. Make one copy for each student.

Things to schedule, set up, or test:

- ☐ 1. Review the online Event Schedule and select at least one live event for students to interact with a NASA Subject Matter Expert.
- ☐ 2. Gather and organize materials from the Materials List for each activity.
- ☐ 3. Test your technology set up to make sure students can see and hear videos, slides, etc.
- ☐ 4. Select a suitable and safe area to deploy drag devices. It could be an open stairwell area balcony or stable ladder. Drops must be from at least two meters high, the higher the better.
- ☐ 5. Check your video or digital cameras to ensure they are fully charged and have enough memory or tape for recording challenge activities.

During the Challenge

- ☐ 1. Distribute Media Release Form to each participating student and set a due date for return.
- ☐ 2. Ask each group of students to come up with a unique team name.
- ☐ 3. Use the Presentation Slides for Students to lead the students through the challenge.
- ☐ 4. Encourage each group to take pictures and video throughout the challenge to use in their final video.
- ☐ 5. Help students prepare questions and information to share with the NASA Subject Matter Expert for the live event for students.
- ☐ 6. Participate in one or more live events for students.

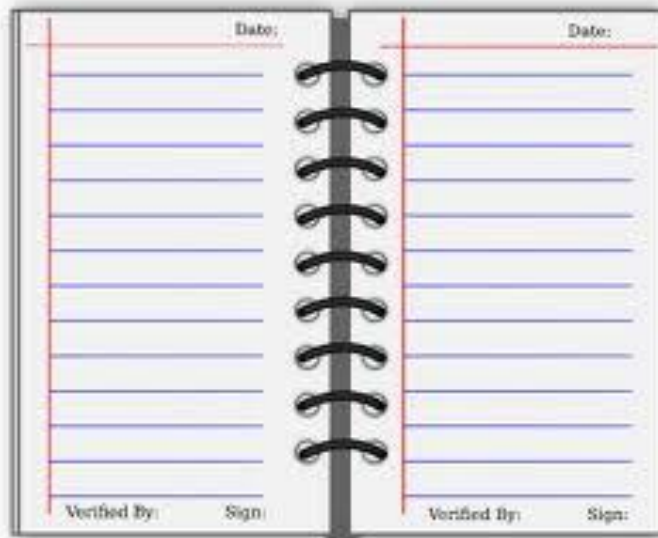
After the Challenge

- ☐ 1. Review Video Criteria and Rubric and Telling Our Story with Video with students.
- ☐ 2. Assist students as they plan and create their final video.
- ☐ 3. Upload student video submissions.
- ☐ 4. Allow enough time to send a separate email with entry information and media release forms for each video by April 16, 2015.
- ☐ 5. Participate in evaluation of the 21CCLC pilot program.

Student Name: _____

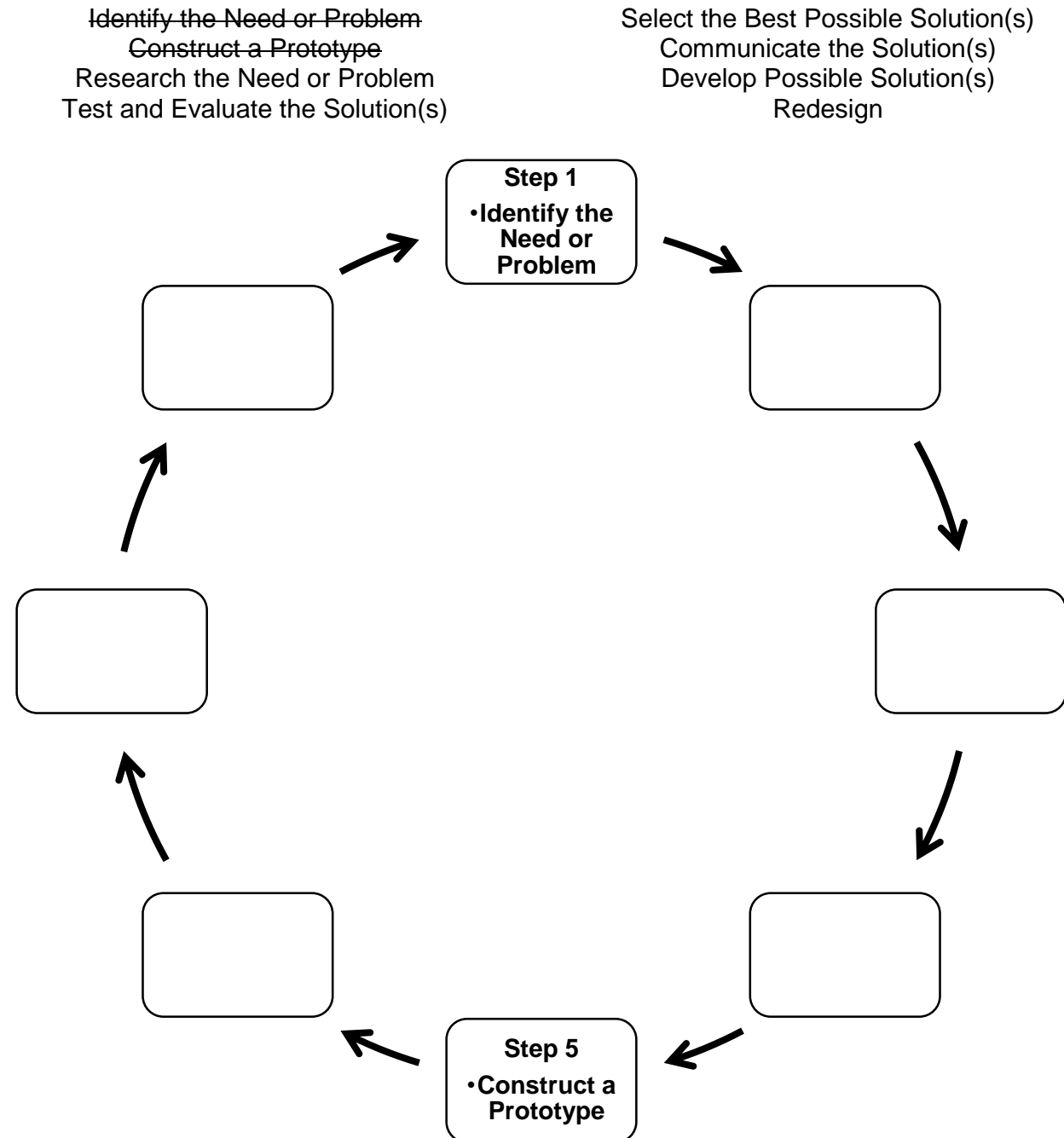
Team Name _____

STUDENT TEAM CHALLENGE JOURNAL



ENGINEERING DESIGN PROCESS

Directions for the Students: Can you determine the sequence that engineers take to make a completed design? On your own, try to label the steps of the Engineering Design Process. Put the rest of the steps below in order based on the two that have already been filled in for you.



KLEW CHART FOR STUDENTS

Student Name: _____

Team Name _____

This Challenge is: _____

KNOW	LEARN	EVIDENCE	WONDER
What do I know about landing on Mars?	What did I learn about landing on Mars based on my research?	What evidence do I have that supports what I learned about landing on Mars?	What am I still wondering about landing on Mars?

CHALLENGE RUBRIC

Use the Challenge Rubric below to assess each team's final design. It may be helpful to have each group explain how they use the Engineering Design Process, Steps 1-8, to create their designs.

Category	Below Target (1)	At Target (2)	Above Target (3)
1. Identifying the Need or Problem	Rephrases the problem with limited clarity and fails to identify criteria or constraints	Rephrases the problem clearly and identifies most criteria and constraints	Rephrases the problem precisely and identifies all criteria and constraints
2. Research the Need or Problem	Need or problem is not well researched and will not be helpful in development of solutions	Need or problem is adequately researched and may assist in development of solutions	Need or problem is thoroughly researched and can easily direct development of solutions
3. Develop Possible Solutions	Contributes implausible ideas or no ideas. Produces incomplete sketches. Does not present a concept	Contributes a plausible idea. Produces marginally accurate sketches of design concepts	Contributes multiple, plausible ideas. Produces accurate sketches of design concepts
4. Selecting the Best Possible Solution(s)	Inadequately analyzes strengths/weaknesses of possible solutions. Does not select a solution based on criteria and constraints of the need or problem	Satisfactorily analyzes strengths/weaknesses of possible solutions. Selects a solution based on some but not all criteria and constraints of the need or problem	Thoroughly analyzes strengths/weaknesses of possible solutions. Selects a promising solution based on thorough analysis of all criteria and constraints of the need or problem
5. Construct a Prototype	Prototype meets the task criteria to a limited extent	Prototype meets the task criteria	Prototype meets the task criteria in insightful ways
6. Test and Evaluate the Solution(s)	Data is inaccurately taken or does not reflect performance of the prototype	Data is taken accurately that reflects the performance of the prototype	Accurate data is taken that reflects the performance of the prototype and will clearly aid in redesign
7. Communicate the Solution(s)	Both the results of testing are not accurately reported and there is no sharing of areas of improvement	Either results of testing are not accurately reported or there is no sharing of areas of improvement	Results of testing are accurately reported and shares insightful areas for improvement
8. Redesign	Refinement based on testing and evaluation is not evident	Refinements made based on testing and evaluation results	Significant improvement in the design is made based on prototype testing and evaluation

Total Score: _____

Team Name: _____

VIDEO CRITERIA AND VIDEO RUBRIC

Video Criteria

Video submissions showcase your prototype and the process it took to go from initial design to final solution and should include the following information.

1. Teams **MUST** use the following script to introduce their video:
 - a. “This is team (team name) and we did the ‘Parachuting onto Mars’ challenge. The title of our video is _____.”
 - b. Do not identify the name of any student, teacher, school, group, or city/region in your video. Submissions that do not follow these directions will be disqualified.
1. Introduce special features and unique qualities of your design.
2. Discuss the results of tests from Step 6 and modifications made to improve the device from Step 8 for each design iteration.
3. Based on your results and modifications, explain your best design solution from Step 4. Be sure to give reasons for your choice.
4. Include photos or video of a summary of your work including drawings of your design, key measurements, and how the prototype was built and tested.
5. Identify any information provided by NASA Subject Matter Experts (SMEs) that helped you in your design or testing.
6. Explain which characteristics of your design provided the most reliable results and why?
7. Based on your results and the modifications you recorded in Step 7, include advice for the engineers working on this project in the future.
8. Total length of video should be three to five minutes.

The following Video Rubric will be used by evaluators to review and score each submitted video based on the above criteria and presentation style.

Parachuting onto Mars

Video Rubric

Student Name: _____

Team Name: _____

This rubric can be used to review and assess the quality of each video. Each category will be scored 0-3 points. Totals for each column will be added for a final score.

Rubric Category	Best 3 points	Better 2 points	Good 1 point	Missing 0 points
Introduction Statement	Special features are stated clearly with additional words and/or images.	Special features are stated but no additional images are included.	Special feature statement is incomplete.	No statement is included.
Drawings	A detailed drawing of the final design, as well as detailed drawings of each iteration are included.	A detailed drawing of the final design is included, but no other iterations.	Rough drawings of the final designs or other iterations are included.	No drawings are included.
Engineering Design Process	All of the phases of the Engineering Design Process are mentioned.	More than four elements of the Engineering Design Process are mentioned.	At least one element of the Engineering Design Process is mentioned.	No mention of the engineering design process is included.
NASA Subject Matter Expert (SME) Comments	Interactions with NASA SMEs are discussed and show how the feedback was incorporated into design or testing.	Interactions with NASA SMEs are discussed and gives details about the feedback they provided.	Interactions with NASA SMEs are discussed in only general terms.	No mention of NASA SME interactions are included.
Video Criteria	All criteria are addressed thoroughly and thoughtfully.	Criteria are addressed.	Some criteria are addressed.	No criteria are addressed.
Photos or Video	Video of the build and test phases are included with additional still shots added.	The build and test phases are included in the photos/video.	Only the build or only the test phase is included in the photos/video.	No photos or video showing the build or test phases are included.
COLUMN SCORE				

Total Score: _____

STEP 1: IDENTIFY THE NEED OR PROBLEM

The Challenge:

When NASA sends spacecraft to land on the surface of Mars, they travel at extreme speeds and need to slow down using some sort of drag device that slows the space capsule to prevent the machinery from crashing into the planet and damaging or destroying it. As missions increase in complexity and capability, the landers and rovers are getting heavier; and therefore, require even more effective drag devices.



You will work in a team to design, build, and test a drag device. You may only use materials provided, and must connect to a team-built cargo bay that is assembled using the template provided. The overall mass cannot exceed 50 grams. The drag device must have at least five separate angled edges (rounded edges are allowed, but one big circle is not allowed). It should protect the weighted cargo bay when it is dropped from a height of at least 2 meters. Surviving higher drops is preferred.

Based on this information and the challenge introductory video, answer the following questions.

1. Using your own words, restate the problem in the form of “How can I design a _____ that will _____?” Be sure to include all expected criteria and constraints.

2. What general scientific concepts do you and your team need to consider to begin solving this need or problem?

STEP 2: RESEARCH THE NEED OR PROBLEM

Conduct research to answer the following questions related to the challenge problem. Cite where you found your information on the line labeled "Source(s):"

1. Who is currently working on this or a similar problem today? What solutions have they created or are working on currently?

Source(s):

2. What questions would you ask an expert who is currently trying to solve problems like this one?

3. Who in our society will benefit from this problem being solved? How could this relate to everyday uses in society?

Source(s):

4. What are some innovative options for using the materials that are available to solve this challenge?

Source(s):

STEP 3: DEVELOP POSSIBLE SOLUTIONS

Sketch your drag device in the space below. Label each part of your drawing. Consider the following questions when brainstorming your ideas.

What shape do you think the drag device should be?

What features would your drag design have?

What materials could you use to design your drag device and capsule?

Are all the criteria and constraints being met by these ideas?

STEP 4: SELECT THE BEST POSSIBLE SOLUTION(S)

Work with your team to analyze each person's final drawing using the table below. Based on the team's discussions, determine which design will be used to solve the problem, and what features will be included to create team's prototype.

Design # Designer Name	Does this design meet all criteria and constraints of the problem?	What are the strong elements of this design?	What elements need to be improved?
1.			
2			
3			
4			

STEP 5: CONSTRUCT A PROTOTYPE

1. Make a final drawing of your prototype. Have it approved by your facilitator.



Approved by: _____

What are the resources that will need to be gathered?

Who in the group is doing what?

Team Member				
Responsibilities in the building process?				

STEP 6: TEST AND EVALUATE THE SOLUTION(S)

1. Record the mass and calculate the surface area of the drag device below. Show your calculations.

Total Mass _____

Surface Area of Drag Device _____

2. Record the drop height _____
3. Drop drag device attached to capsule while timing descent. After each drop, note any damage to the drag device or capsule. Each device should be dropped three times and results averaged together. For advanced students, calculate the speed. Record results in table below.

Drop #	Time (sec)	Speed (cm/sec)	Note any damage after each drop.
1			
2			
3			
Mean Average			

STEP 7: COMMUNICATE THE SOLUTION(S)

It is not enough to simply produce raw data. Scientists and engineers need to interpret the data so that they can convince others that their results are meaningful. This step will help you summarize how your design changed through multiple iterations of the engineering design process. Start by filling out the table about your initial prototype.

Iteration #	What are the key components to your initial prototype?	What do you think caused the design to succeed or fail during testing and why do you think that?
1		

All modifications to your design, both major overhauls and minor tweaks, should be recorded below to track the changes made. After every phase of tests, complete the chart below by describing changes and summarizing what results the testing showed.

Iteration #	What was added, removed, or changed in this iteration of your design?	What do you think caused the design to succeed or fail during testing and why do you think that?
2		
3		
4		
5		

STEP 8: REDESIGN

Did this iteration of your design meet all of the constraints of the original problem? _____

What problem(s) did you discover while testing this iteration?

What will you do to try to improve your design based on this data?

How do you predict that these changes will improve over the iteration you just tested?

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What was the greatest challenge or challenges for your team today?
2. What strategy or strategies did your team prove effective in overcoming your greatest challenge?
3. How did you use the Engineering Design Process to help you with your design?
4. Which drag device design characteristics provided the most reliable results?
5. Which design had the slowest descent (longest drop time)?
6. What was discovered about the relationship between surface area and drop time?

BUDGET PLANNING WORKSHEET

Team Name: _____

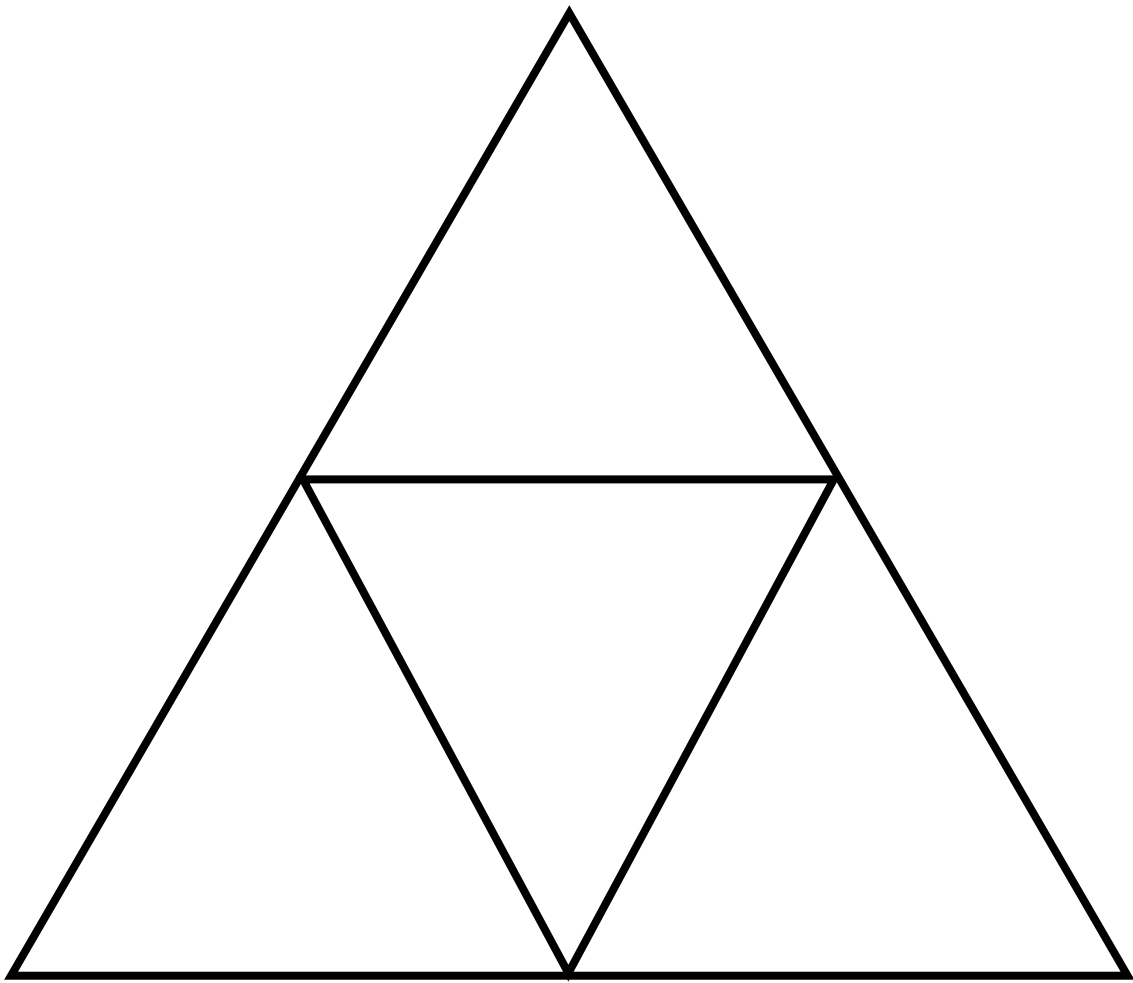
Directions: As a team, complete the cost sheet below. Be sure to include all of the materials that are needed, quantity, unit cost (determined by your facilitator), and the final total to complete your design. Try to use the least amount of materials to keep the cost of your design low.

Line Item Number	Material	Unit Cost	Quantity	Item Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

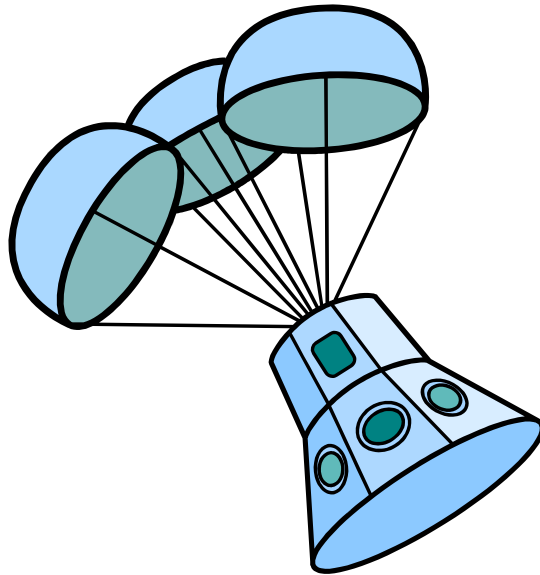
TOTAL COST _____

Capsule Template

Cut out larger triangle and fold on inner lines to create a pyramid shape. Put the simulated payload (plastic bag of mass) inside the pyramid shape and tape up the sides. You might need to adjust the weight of your capsule during testing, so be sure not to use too much tape.



SUPPORT MATERIALS



NASA RESOURCES

Videos

APOLLO 15 Hammer and Feather – <https://www.youtube.com/watch?v=03SPBXALJZI>

Curiosity's Seven Minutes of Terror – http://solarsystem.nasa.gov/multimedia/video-view.cfm?Vid_ID=1642

Mars in a Minute – How Do Rovers Drive on Mars? – <http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=37>

Mars in a Minute – How Do You Get to Mars? – <http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=26>

Mars in a Minute – How Do You Land on Mars? – <http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=30>

Mars in a Minute – Is Mars Really Red? – <http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=25>

Supersonic Decelerator on 'Right Track' for Future Mars Missions – https://www.youtube.com/watch?v=1G9QPsTjP0Q&feature=share&list=PLBEXDPatoWBIJU2U76iArz5U8SqVj8_7

Websites

Space Place Mars Adventure – <http://spaceplace.nasa.gov/mars-adventure/en/>

Low-Density Supersonic Decelerators (PDF) – http://www.nasa.gov/pdf/737628main_Final_LDSD_Fact_Sheet_3-26-13.pdf

<http://spaceplace.nasa.gov/mars-adventure/en/>

For more information and to access the Help Desk, visit the 21CCLC NASA STEM Challenge website at <http://y4y.ed.gov/stemchallenge/nasa>.

EXTENSION ACTIVITIES

MORE FUN WITH ENGINEERING

Activity One: On a playground or large outdoor area, measure out the diameters of the three decelerators that NASA is currently designing as part of LDSD, 6 meters, 8 meters, and 30 meters.

Activity Two: *Atmospheric Conditions*

In your classroom experiments, you probably didn't have to worry too much about wind conditions, temperature, atmosphere, etc., like NASA engineers do when they are preparing for missions to Mars. NASA engineers have only landed massive spacecraft on Mars a few times, so in preparing for these future missions, they must make predictions on what the atmospheric conditions will be like for these future Mars landings. With these predictions of conditions, they then attempt to simulate entry conditions on Earth to be sure the spacecraft can handle a variety of situations.

The Mars Science Laboratory Entry Descent and Landing Instrument (MEDLI) sensors captured detailed data about the atmospheric conditions when Mars Science Laboratory landed in August 2012. This information will help engineers to mimic the conditions of Mars during their simulated Low Density Supersonic Decelerator (LDSD) entries to Earth. Very soon engineers will be testing the LDSD designs at supersonic speeds in Earth's stratosphere. Based on the new data, they will make even more precise predictions of what they can expect on an entry to Mars. This information will help ensure mission success!

Research what is known about the atmospheric conditions on Earth and Mars.

<http://quest.nasa.gov/aero/planetary/mars.html><http://quest.nasa.gov/aero/planetary/mars.html>

<http://www.nasa.gov/offices/marsplanning/faqs/index.html><http://www.nasa.gov/offices/marsplanning/faqs/index.html>

<http://www.nasa.gov/offices/marsplanning/faqs/index.html>

- What environmental or weather conditions do you think they should try to simulate on Earth ahead of time?
- Which conditions do you think would have the largest effect on the design?
- Based on the designs you did today, how would your overall design concept perform on the entry phase to Earth? To Mars?

Follow the latest developments and research at

http://www.nasa.gov/mission_pages/tdm/ldsd/index.htmlhttp://www.nasa.gov/mission_pages/tdm/ldsd/index.html

FOUR FORCES OF FLIGHT

Description: The Four Forces of Flight game helps students learn the terms associated with flight: lift, thrust, drag, and weight.

Objectives: The students will:

- Identify the four forces of flight: lift, thrust, drag, and weight.
- Explain how the four forces of flight affect the direction of flight of an airplane.
- Classify which forces of flight are positive and which forces of flight are negative (which forces oppose each other).
- Construct and play an aviation game

National Standards:

National Science Education Standards, NSTA

Science as Inquiry

- Understanding of scientific concepts.
- An appreciation of “how we know” what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skills, abilities, and attitudes associated with

Physical Science Standards

- Position and motion of objects.
- Motions and forces.

Science and Technology Standards

- Abilities of technological design.
- Understanding about science and technology. Common Core State Standards for Mathematics, NCTM.

Operations and Algebraic Thinking

- Use the four operations with whole numbers to solve problems.
- Generate and analyze patterns.

Operations and Algebraic Thinking

- Write and interpret numerical expressions.
- Analyze patterns and relationships.

National Geography Standards, NCGE

The World in Spatial Terms

- How to use maps and other geographic representations, tools, and technologies to acquire, process and report

Parachuting onto Mars

UNIT: Physical Science -- Aeronautics

GRADE LEVELS: 4–6

CONNECTION TO CURRICULUM: Science, Mathematics, and Technology

TEACHER PREPARATION TIME: 1 hour

LESSON TIME NEEDED: 1 hour Complexity: Basic science.

MATERIALS

- Game board.
- Game piece, game cube tube information from a spatial perspective.

ISTE NETS and Performance Indicators for Students, ISTE

Creativity and Innovation

- Use models and simulations to explore complex systems and issues. Critical Thinking, Problem Solving, and Decision Making
- Plan and manage activities to develop a solution or complete a project management copy game board, game pieces a game cube on card stock paper. Laminate game board, game pieces, and game cube, so they will be more robust, and collect them to reuse again in future classes. Students play the game in small groups (from two to four).

Content Research

Key Concepts: The four forces of flight: lift, thrust, drag, and weight

- Lift is a force that acts upward against gravity and makes it possible for aircraft to rise in the air.
- Thrust is a forward force that pushes an aircraft through the air.
- Drag is the force of resistance to the motion of a vehicle body as it moves through a fluid such as water or air; drag acts in the opposite direction to thrust.
- Weight is a response of mass to the pull of gravity. It acts downward against lift. (Gravity is the force that pulls down on objects and gives them weight.)
- What are opposing forces? Lift works opposite of weight. Thrust works opposite of drag.

Opposing forces (lift and weight; thrust and drag; positive and negative):

- Lift works opposite of weight.
- Thrust works opposite of drag.
- Positive direction is either up or forward and negative direction is down or backward.

Misconceptions:

Weight and gravity are the same on Earth and are sometimes used interchangeably.

Weight is a response of mass, and gravity is a force that gives weight.

Parachuting onto Mars

(Note: This distinction is beyond the 4–6 grade level, but this is additional knowledge for the teacher and can be discussed if a student brings up the question from seeing weight and gravity used interchangeably in a four forces diagram.)

Lesson Activities (PDF) – http://www.nasa.gov/pdf/636827main_Sci%20Filesguide4_00.pdf

The Four Forces of Flight board game is played by students who use the four forces of flight to be the first to fly from Thrust City airport to Liftville airport. The board game contains problem solving.

Additional Resources

The Beginner's Guide to Aeronautics Home Page –
<http://www.grc.nasa.gov/WWW/K-12/airplane/index.html>

- Aircraft Motion -- interactive simulators, animated movies.
- Airplane Parts -- interactive, fact sheets.
- Aircraft Forces -- interactive, animated movies.
- Thrust -- interactive simulator, fact sheets.
- Weight -- movies, fact sheets.
- Lift -- interactive, interactive simulator, animated movies.
- Drag -- interactive simulator, fact sheets.
- Gliders -- fact sheets, paper templates.
- Wind Tunnels -- interactive simulator, fact sheets.

The Courage to Soar Educator Guide

Activity Eight -- The Four Forces of Flight (PDF) –

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/The_Courage_to_Soar.html

- Lesson 15 – The Four Forces of Flight at Work.
 - Vocabulary list, student text, and diagram.
- Lesson 16 – The Pull of Gravity.
 - Vocabulary list, student text and six gravity experiments.
- Lesson 17 – It Lifts Me Up -- The Force of Lift.
 - Vocabulary list, student text, diagram, and six lift experiments.
- Lesson 18 – The Opposing Forces of Thrust and Drag.
 - Vocabulary list, student text, and experiments.
- Lesson 19 – Thrust and Drag Experiments.
 - Vocabulary list, student text, three thrust experiments, and three drag experiments.

The 1902 Glider – How the Problem of Control Was Solved (PDF) -

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/1902_Glider.html

- Poster and Web-based resources to integrate into classroom activities.

Discussion Questions

- What is force? - Force is a push or pull used to lift something, start it moving, or hold it in place against another force.
- What is lift? - Lift is a force that acts upward against gravity and makes it possible for aircraft to rise in the air.
- What is thrust? - Thrust is a forward force that pushes an aircraft through the air.
- What is drag? - Drag is the force of resistance to the motion of a vehicle body as it moves through a fluid, such as water or air; drag acts in the opposite direction to thrust.
- What is weight? - Weight is a response of mass to the pull of gravity. It acts downward against lift.
- What is gravity? - Gravity is the force that pulls down on objects and gives them weight.
- What are opposing forces? - Lift works opposite of gravity. Thrust works opposite of drag.

Assessment Activities

- Have students describe the four forces of flight, listing the parts of an airplane that affects each of the four forces.

Extensions

- Add fuel consumption to the problem.
- Make a new game board that favors a different spinner.
- Make new spinners that would best suit the game.
- For advanced students, create a game board that would involve positive and negative integers and that would extend into other quadrants of the coordinate plane.

GLOSSARY OF TERMS

Aerodynamics – the qualities of an object that affect how easily it is able to move through the air

Capsule – a pressurized modular compartment of an aircraft or spacecraft, one designed to accommodate a crew or to be ejected

Cargo – freight carried by an aircraft or other transportation vehicle

Constraints – the limits placed on the design due to available resources and environment

Criteria – standards by which something may be judged or decided

Decelerator – a mass or object that decreases the speed of another object, slow the object down

Descent – the downward incline or passage of an object

Drag – the force opposite of thrust; it slows objects down in the atmosphere

Exploration – the act of investigating systemically an objective for the purpose of discovery

Fragile – easily broken or damaged

Gravity – the force that attracts a body toward the center of the earth, or toward any other physical body having mass.

Independent variable – a value that is determined without support by other traits

Inferring – to conclude from evidence rather than from definitive statement of fact

Iteration – one cycle of a repetitive process

Launcher – a device for firing rockets

Mass – a unified body of matter without any specific shape

Model – a small object, usually built to scale, that represents another larger object

Observation – the act of noting and recording something with an instrument

Orbit – the path of a celestial body or artificial satellite as it revolves around another object

Prediction – the act of attempting to tell beforehand what will happen

Payload – things carried by a spacecraft

Robotics – the study and application of a mechanical device that works automatically or by remote control

Template – a pattern used to guide in making something accurately

Thrust – force that opposes gravity

Volume – is the quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance (solid, liquid, gas, or plasma) or shape occupies or contains

Weight – the force on an object due to gravity



“The most important thing we can do

is inspire young minds and to advance the kind of science, math and technology education that will help youngsters take us to the next phase of space travel.”

**Senator John H. Glenn, Jr.,
NASA Astronaut and United States Senator**



National Aeronautics and Space Administration

John H. Glenn Research Center
21000 Brookpark Road
Cleveland, OH 44135

www.nasa.gov

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